THE FIRE FACTOR IN RELATION TO THE VEGETATION OF WESTERN AUSTRALIA

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I. ORIGIN OF FIRES AND THEIR PERIODICITY.

It can be accepted in the first place that fires have occurred with varying frequency over a considerable portion of Australia as a natural phenomenon. A study of the flora and its growth forms, together with certain adaptations to meet these requirements, lends powerful support to this theory.

The long drought period which prevails annually over the greater part of Western Australia, usually of seven or eight months' duration (if we except the extreme South-West) together with the high prevailing temperatures and low relative humidity, provide the necessary requirements for bush fires. Added to this we must include as factors favouring fire the aestivating character of the woody flora, and the presence in a large number of plants of essential oils in considerable amounts, especially in the families Myrtaceae and Rutaceae. Anyone who has seen a raging bush fire in dense mallee scrub, when gaseous material flares high above the vegetation, can appreciate this fact.

Bush fires appear to be most prevalent, or to have the most marked periodicity, in the heath lands and the mallee thickets, in which conflagrations of extensive occurrence have been observed, some of them travelling on a broad front for many miles, leaving in their trail bare soil, or a landscape in which only dead stems remain. Such fires do not occur to the same extent in the sclerophyllous woodland country (with the possible exception of the jarrah forest), nor do they appear to be a feature of the mesophytic forest areas under natural conditions. If they occur naturally in the mulga bush, they do not appear to be as extensive, or to inflict the same damage.

Under natural conditions fires appear to originate mainly by lightning, especially in lateritic or haematitic country. The writer has on more than one occasion seen definite evidence of such fires, as for example on Mount Lesueur in 1931, where two fires had been so caused, but had, apparently been extinguished by rain. On the hill at Mingenew there are few adult trees that have not been damaged by lightning. The chances of lightning-caused fires are enhanced during dry summer thunderstorms, especially in heath country. Farmers are well aware of the danger of fires due to lightning in ripe crops, and there are many cases on record. Foresters also have experienced similar occurrences.

There are early references to bush fires in Western Australia. Robert Brown in his diary describes in the summer of 1801-1802, bush fires close to the south coast of Western Australia. John Lort Stokes in *Discoveries in Australia* (vol. II, 1846, p. 228), writing of an excursion to the north of King George's Sound, states: "On our way we met a party of natives burning the bush, which they

do in sections every year. The dexterity with which they manage so proverbially a dangerous agent as fire is indeed astonishing. Those to whom this duty is specially entrusted, and who guide or stop the running flame, are armed with large green boughs, with which, if it moves in a wrong direction, they beat it out. Their only object in these periodical conflagrations seems to be the destruction of the various snakes, lizards, and small kangaroos called wallaby, which with shouts and yells they thus force from their covert, to be despatched by the spears or throwing sticks of the hunting division." The writer has observed a similar practice in North Kimberley during the dry season. Indeed, this aspect of the biotic factor as affecting the flora may well extend back over a very long period—long enough to have affected the structure of plant communities by finally eliminating any species unable to survive fire damage.

II. THE EFFECT OF FIRES.

The effect of the bush fire varies with the nature of the formation. In shrub heath and mallee thickets, if of sufficient density, the effect is the total destruction of the aerial parts of the woody plant. This is particularly true of those formations dominated by *Eucalyptus* and *Melaleuca*—both genera rich in plants yielding essential oils. All that remains after the fire are the woody bulb-like bases of the mallee *Eucalyptus* and certain species of *Melaleuca* with similar structures (e.g., *Melaleuca uncinata*). In the savannah formations of the tropics the grass and other herbaceous growth is destroyed, but many of the trees, especially the bloodwoods, ironbarks and smooth-barked "gum trees," are unaffected. Most species of Acacia and the Proteaceae are liable to be killed outright, but some with a thick suberose bark, such as *Acacia pyrifolia,* and a number of cork-barked species of *Hakea,* are unaffected. The dry grass carries a fire which is rapid in action, so that its heating effect on the trees is relatively transient. It would be interesting to know to what extent the talc-like outer bark of certain smooth-barked species of *Eucalyptus* is fireproof, since these trees appear to be remarkably fire resistant.

The open nature of the mulga formation, and the presence of so much plant debris on the surface of the soil, would indicate that fires are not an occurrence of frequent periodicity in this formation, and here again, the highly inflammable nature of the dried Compositae would result in a rapidly moving fire unable to burn the rough and hard-barked mulga shrubs and trees.

In the sclerophyllous woodland of the interior the effect of fire is not well marked, except where mallees occur in thicket formation. This is probably owing to the open nature of these formations, and the smooth-barked trees which rarely catch fire unless there is considerable plant debris around their bases.

In the mesophytic formations such as the karri forest it is doubtful if fires have occurred on any scale as a natural phenomenon. The accumulated decayed trunks and branches of

trees, and the deposits of humus lend some support to this. On the other hand, in this formation, fires when started through human agency, can be particularly destructive, causing a coppicing from the tree trunks which has not been observed in the virgin forest.

Following upon burning in the sclerophyllous heath and thicket formations, there is an almost immediate regrowth of the woody plants. The young shoots are of rapid growth, and, together with the same foliage, are characterised in many instances (notably in the Proteaceae, Papilionaceae and Myrtaceae) by the presence of anthocyanin, which imparts to them a reddish appearance. Probably, as a result either of added potash to the soil, or perhaps through a reduction in root competition between the plants, the species grow more rapidly, and flower more freely as a result of burning. It may be that flowering results more freely from the young active growth compared to the slower growth on the unburned plants. *Nuytsia floribunda* which is never destroyed by fire certainly flowers much more freely in the year immediately following a fire than in other years, when flower production can be extremely poor.

III. THE EFFECT OF PROTECTION FROM FIRE IN THE SCLEROPHYLLOUS THICKET FORMATIONS.

There is an area comprising about 90 acres to the north of Tammin, which has been protected from fire for over 50 years. It consists mainly of thickets of *Casuarina acutivalvis, Acacia neurophylla, Hakea multilineata, Eucalyptus leptopoda* and *Eucalyptus burracoppinensis,* with more open spaces of *Ecdeiocolea monostachya.* For some years now this area has assumed a peculiar aspect by reason of the amount of dead wood present, by the almost impenetrable nature of the thickets, and by the very small amount of foliage present on the Casuarinas. Some of these have very small crowns at the apex of their stems, which are characterised by the production of so much dead wood, perhaps as a result of a reduction in light, or from lack of space for development. These are not usual conditions and such features have not been observed generally under present day natural conditions. It would be interesting to observe the effects of a fire on this area.

It appears, also, that prolonged freedom from fires renders a habitat less favourable to animals. G. Bornemissza, in a study of arthropod faunas in The King's Park, Perth, has demonstrated that areas long unburned were poorer in arthropod numbers than recently burned areas. He showed that the fauna will return to its original composition after any kind of fire, the rate depending largely on the soil type and particularly on the rate of regeneration of the flora (*Proc. Pan Indian Ocean Sci. Congress,* Sect. B & D, pt. 1, 1954, p. 4).

IV. ADAPTATIONS

a. THE CAUDEX

In a large number of indigenous plants there is present an abbreviated woody axis from the upper surface of which a number

of stems arise, while from the lower portions the roots are given off. This type of growth is typical of those species of *Eucalyptus* known popularly as *mallees*, as well as by a number of unrelated plants. Examples are found in *Casuarina grevilleoides* which produces its cones on this bulb-like structure, and a number of Proteaceae, especially *Isopogon* and *Petrophila*, *Conospermum*, *Adenanthos*, *Strangea*, some species of *Grevillea* and *Hakea*, *Banksia* and *Dryandra*. *Daviesia epiphylla* offers a good example for the Papilionaceae, and further examples occur in the Tremandraceae, Stereuliaceae and Dilleniaceae. Amongst the Myrtaceae, apart from *Eucalyptus*, there are a number of bulbous-based species of *Melaleuca*.

In the genus *Eucalyptus* there are nineteen species which occur only in the mallee form. These are—*E. cylindriflora*, *E. decurva*, *E. diversifolia*, *E. doratoxylon*, *E. ebbanoensis*, *E. erythronema*, *E. eudesmioides*, *E. grossa*, *E. incrassata*, *E. macrocarpa*, *E. seyphocalyx*, *E. Sheathiana*, *E. tetragona*, *E. tetraptera*, *E. uncinata* and *E. coronata*. The remaining species of the genus in

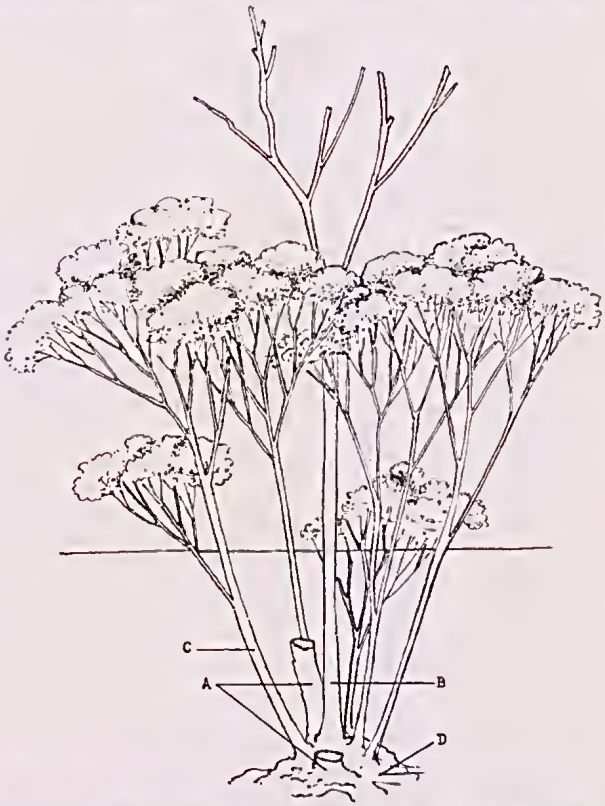

Fig. 1.—Sketch illustrating the growth form of a typical mallee and exhibiting:—A, old stems (usually termite eaten) destroyed by fire. B, later regrowth killed by fire, but not destroyed. C, current regrowth from adventitious buds in mallee stock. D, mallee stock.

Western Australia occur as trees or shrubs, a number of which may occur both in the tree and mallee form, especially those species which belong to the Oleosae, the Dumosae and the Cornutae. The tree forms occur in the sclerophyllous woodland, whilst the mallees are found either fringing the woodland, in thicket formation, or on the heaths. A number of the Western Australian species of *Eucalyptus* are found only in the tree form, and never as mallees. Such are *E. diversicolor, E. Jacksonii, E. Guilfoylei* and *E. calophylla* of the mesophytic forest areas, although *E. calophylla* may be found as a shrub in the Stirling Range and vicinity. All the tropical species occur as trees, and a number of the sclerophyllous woodland species remain always as trees, e.g., *E. salmonophloia, E. salubris, E. torquata, E. Stricklandii, E. Brockwayi, E. LeSouefii, E. Dundasi* and several others.

It is therefore significant that the mallee type of growth is associated with those formations in which fires usually occur. Characteristic of the mallee is its ability to produce vegetative shoots from the woody stock annually for very long periods following the destruction of the aerial shoots, and to produce flowers and fruits on stems frequently only two or three years old.

In those species which possess both the tree and the mallee form it is possible to convert the former to the latter by injury to the stem. This is done by artificial burning, by cutting, or by bush fire. All of these species have a broad pedestal-like, or bulb-like base to the trunk. There are very few exceptions to this rule.

The mallee formations of Western Australia are restricted to the thicket and shrub heath country of the South-West Province, and to the winter rainfall area of the Eremaea. They are entirely absent from the tropics, and from the mesophytic formations of the South-West, and are comparatively rare in the open woodland formations.

Fire often results in the death of the tree, particularly such trees as *E. salmonophloia* and *E. salubris,* but in the mallee country there is immediate regeneration by vegetative shoots from adventitious buds on the bulb-like stock. The mallee structure is particularly adapted to resist burning, even when severe.

b. THE FRUIT.

The fruits of a number of indigenous species are peculiar in that after the maturation of the seed, the fruit (either a cone, follicle or capsule) remains undehisced until the death of the plant or the branch which bears the fruits, or following a fire. The most notable examples of these are to be found in *Hakea, Xylomelum* and *Banksia,* as well as in a large number of the capsular-fruited Myrtaceae (eg., *Eucalyptus, Melaleuca, Callistemon, Calothamnus, Leptospermum, Regelia,* etc.). Further examples are provided by *Casuarina* and by *Callitris* and *Actinostrobus.* In many species of *Banksia* the cones (follicles) do not dehisce even when removed from the plant, and the seeds can be liberated only by mechanical action, or by heat. A similar phenomenon is exhibited by *Casuarina,* and by *Callitris* and

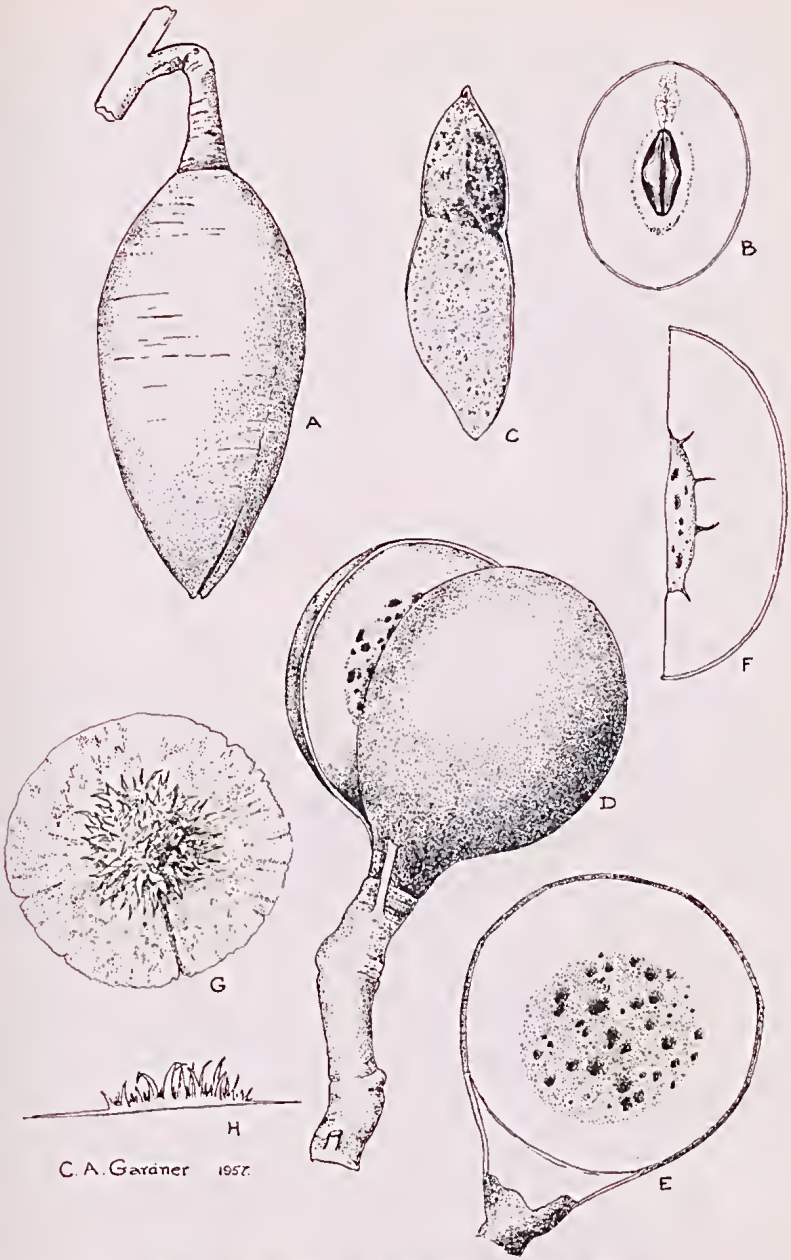

Plate 1.—Fruits of *Xylomelum* and *Hakea*.

Xylomelum angustifolium Kipp. A, fruit. B, section of same. C, seed. *Hakea platysperma* Hook. D, dehisced follicle. E, half of opened follicle, showing crater-like pits which receive the processes of the seed "nucleus". F, section of half of follicle, showing cavities in section. G, seed, showing processes. H, lateral view of seed showing processes in elevation. × 4/5.

Actinostrobus, although these will usually dehisce after a period of drying.

When these plants are burned by a bushfire, the fruits (braeteoles in *Casuarina*) open immediately. The seeds are not immediately shed, however. The cones of *Callitris* and *Actinostrobus* retain the winged seeds in position, and these are liberated by wind. In *Casuarina* the valves usually open horizontally, so that the achenes remain *in situ* for a time, being tardily liberated by mechanical action such as wind. The same holds true for *Banksia*. The follicles of *Hakea* and *Xylomelum* open vertically, but the seeds are retained in the fruit for a time, being attached to the follicle by the tip of the seed-wing, or by processes from the seed itself which are embedded in corresponding cavities in the follicle. Examples of this are provided by *Hakea platysperma* and *H. crassifolia*, which have muricate seeds the processes of which penetrate deeply into the woody carpel. It is worthy of note that all the above are provided with wings, a feature of importance which enables the seeds to be deposited some distance from the parent plant. It is further worthy of note that these plants belong to primitive groups (*Cupressaceae*, *Casuarinaceae* and *Proteaceae*). The mechanism of these ensures that the seeds do not fall into hot ashes, their dispersal being delayed.

c. THE SEED.

A large number of the indigenous species possess what are termed "hard seeds." These after the dehiscence of the fruit retain their viability for several, often many, years, and often do not germinate until a fire has occurred. This is particularly true of a number of the Papilionaceae. Indeed, farmers well know the risk of losing stock from toxic species of *Gastrolobium* and *Oxylobium* following a fire in country where the plants have not been seen for several years. There are numerous examples of these hard-seeded plants. Other species, which apparently do not possess hard seeds, make their appearance only after fires, and few live for more than a few years. The annual, *Actinotus superbus* (Umbelliferae), is perhaps the most notable of the herbaceous species. Amongst the woody plants are a number popularly known as "fire-bushes"—plants which make their appearance in the season following burning, and live usually for a limited period. Familiar examples of these are:

Santalaceae: *Exocarpus spartea*
Gyrostemonaceae: *Gyrostemon* spp.
Codonocarpus cotinifolius
Euphorbiaceae: *Ricinocarpus velutinus*
Sterculiaceae: *Hannafordia* spp.
Keraudrenia integrifolia
Verbenaceae: *Lachnostachys* spp.
Goodeniaceae: *Velleia discophora*

It is perhaps worthy of note that the above are all species of the sand heaths, or of the gravelly thicket country.

SUMMARY

It is postulated that there is sufficient evidence to show that fire as a factor affecting plants is one that has been in existence from remote times, and that the flora of Australia, in part, is pyrophilous. The growth form of the mallee *Eucalyptus*, its power of repeated regeneration almost indefinitely from its woody stock by means of adventitious shoots, and its habitat, all favour this theory. The structure of the fruit in certain primitive families well illustrates the adaptation of the plant to fire, and will allow of no other explanation. The general response of the flora following burning of a periodic nature, including the existence of several species of the so-called "fire-bushes," still further supports this theory. Evidence has been advanced showing that absolute protection from fire in the thicket formations has a detrimental effect on the vegetation.

ADDITIONS TO KNOWLEDGE OF THE RANGES OF WESTERN AUSTRALIAN MAMMALS

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Accurate knowledge of the geographic distribution of animals enables the zoologist to define their ecological requirements and limitations. This information is indispensable to the palaeontologist who attempts a palaeo-ecological reconstruction of a fauna. The changes in the areal distribution of animals through time are often indications of changes in the environment.

European settlement and the introduction of European animals have resulted in the disappearance of the Australian fauna over much of its range. Unfortunately, insufficient collecting was done before this disappearance to accurately define the ranges of many species. In many cases this information is irretrievably lost. However, valuable information on mammalian distribution has been contributed by Shortridge (1910), Glauert (1934) and Tate (1947, 1948, 1951). To this it is possible to add some information on animal distribution from the recent bones found in caves along the south and west coasts of Western Australia.

The material upon which this study is based was collected from cave deposits extending along the west coast from Jurien Bay to Cape Leeuwin, and along the Eyre Highway from Cocklebiddy Tank to Eucla. These bones are the remains of prey brought in by owls and carnivores which used the caves for shelter. The nocturnal mammalian fauna is probably well represented in the owl pellet deposits, as owls are known to be good collectors. The larger marsupials are usually represented by juveniles which would be easier to capture. Introduced forms such as rabbits and *Mus musculus* occur on the surface in every cave.

Only specimens from the topmost one foot and the surface are considered in this study. The time interval represented by this thickness of sediment is probably not great. The assemblages